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SCIENCE

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PRINCIPLES OF WATER-POWER DEVELOPMENT¹

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1. The development of water-power involves artificial regulation of streams. Proper regulation of running water for the several uses of water supply, irrigation, power and navigation can be effected only in the light of the physical relations, the relations in equity, and the more salient legal relations of water in streams.

PHYSICAL RELATIONS

2. The fresh water of the land is derived directly from rainfall (including snow) and indirectly through evaporation from the sea. The mean annual rainfall on mainland United States ranges from less than 5 to over 100 inches, averaging 30 inches; the quantity aggregates about 5,000,000,000 acre-feet.² The distribution is unequal; over the eastward two fifths of the country the mean is about 48 inches, over the median fifth some 30 inches, and over the westward two fifths about 12 inches.³

3. In humid lands the water of rains and melting snows tends to gather into streams, generally taking the shortest and easiest paths to the sea, while in arid lands

¹ Presented at a hearing of the National Waterways Commission, November 21, 1911.

² The acre-foot is a convenient unit not only because in common use throughout arid America, but because large enough to measure water in its national aspect without use of incomprehensibly large figures. It equals 43,560 cubic feet, 326,047 gallons, or 1,359.6 tons; it is something over a kilostere (equaling 1.2335 ks.), or cube of 10 meters.

³ “Soil Erosion,” Bureau of Soils Bulletin 71, 1911, p. 17.

(except in a few rivers fed by the greater rain and snow of mountains) it tends to spread into *débris-laden* sheetfloods and will not flow down to the sea; lakes, in which water lodges for a time, are essentially expansions of streams due to what may be called geologic accidents—*e. g.*, the Great Lakes chiefly to glacial scouring, the Millelacs to the irregular configuration of glacial-drift surfaces, Great Salt and Winnemucca Lakes originally to warping of the earth-crust; waterfalls, in which power is easily developed, are also due to geologic accidents—*e. g.*, Niagara and Genesee and St. Anthony to conditions attending withdrawal of the Pleistocene glaciers, the cataracts of the Susquehanna and Potomac and James and the Dalles of the Columbia to displacement in the earth-crust.

4. In humid regions (including mountains in which rain and snow are more abundant than over neighboring lowlands) the streams carry a part only of the water reaching the surface—*i. e.*, the run-off, averaging about one third of the rainfall; about half the aggregate is evaporated, partly from the soil and open waters though more freely from growing vegetation, forming the fly-off; while a smaller fraction (the cut-off) passes deeply into the earth to be absorbed in chemical combination or carried subterraneously to the sea. In arid regions there is (normally) no run-off, and all the water except the small cut-off is evaporated to temper the local climate.

5. In a state of nature—and also under intensive cultivation—little if any storm water flows over the land surface apart from the streams; the rainfall is absorbed by the soil and its vegetal growth, and the streams are supplied partly by springs but much more largely by seepage directly into their channels—this being the normal con-

dition, in which streams are generally clear and nearly uniform in flow.

6. Under certain conditions attending settlement, especially with injudicious clearing and negligent cultivation, a considerable part of the rain falling during storms runs off the land surface, erodes the soil, renders streams turbid, gathers into destructive floods, and introduces wide fluctuations in flow (this representing what may be deemed a temporary condition in the history of the country, and one remediable by proper classification and use of the lands for purposes to which they are adapted, and by intensive cultivation of areas devoted to the growing of seasonal crops).

7. All parts of each stream are interrelated; increase or decrease in volume, inwash of detritus, the initiation of fluctuation, or other changes in regimen at any point eventually affect the stream throughout; especially susceptible to disturbance at the sources are clarity and steadiness of flow at points whence water supply is commonly taken, in the middle course where power development is customary, and in the lower course devoted to navigation.

8. Normal streams, being derived chiefly from seepage, are maintained directly by the store of water accumulated in the ground as the residuum of rains of preceding seasons and decades, and only indirectly by the current rainfall. In the humid part of this country the ground water within the first hundred feet from the surface has been estimated at some 25 per cent. of the volume of subsoil and rock, equivalent to 6 or 7 years' rainfall—*i. e.*, it may be conceived as a reservoir of water 25 feet deep coinciding in area with the humid region. This reservoir is the chief source of the streams available for water-power and other purposes; it is also the reserve agricultural capital of the country,

and the measure of productivity and habitability.

9. Under extensive clearing and cultivation, the store of ground water has been materially depleted. Recent determinations based on records (covering a mean period of about 22 years) of 9,507 wells in the nine states of Illinois, Indiana, Iowa, Kentucky, Michigan, Minnesota, Ohio, Tennessee and Wisconsin reveal lowering of the water-table at a minimum mean rate of 1.315 feet,⁴ or with moderate allowance for new wells 1.73 feet, per decade, corresponding to an aggregate of 13.8 feet for the 80 years since settlement began. This lowering of the level of saturation corresponds with an actual loss of water averaging 5.2 inches per decade, or nearly 150,000,000 acre-feet annually within the nine states. The loss is due largely to increased run-off in freshets and floods, which are in increasing degree wreaking destruction of property and loss of life; while innumerable springs and smaller source streams have disappeared, and the regimen of nearly all streams has been impaired.

10. The rate of subsidence of the water-

table varies from state to state; in those enumerated it declines from 2.464 feet per decade in Minnesota to 0.8 foot in Ohio, while in Missouri it is but 0.43 foot. When the variable rates are coordinated with the geographic relations of the several states, it becomes clear that the ground-water reservoir of the entire interior is continuous, that Missouri is supplied in part by underflow from the Plains and Rocky Mountains, that the level in Ohio is kept up in part by seepage from Lake Erie (explaining that discrepancy between inflow and discharge from the lake which has led to excessive estimates of evaporation), and that Minnesota has merely lost proportionately with the absence of external sources of supply—in short that throughout this area of 532,402 square miles (and presumably elsewhere in the humid country) the reserve store of ground water is not only continuous and fairly conformable to the land surface but moves slowly down-slope in directions generally corresponding with those of the surface streams.

11. The recent researches demonstrate that the surface streams of the humid coun-

⁴The records are summarized in the table following; the detail figures appear in the Yearbook of the Department of Agriculture for 1911 under the title "Subsoil Water of Central United States."

State	Dates		Total No.	Wells Mean Depth	Bi-state Wells			Mean Lower- ing	Water-tables		Mean Lower- ing per Decade
	No.	Mean			Total	Un- changed	Changed		Total No.	Mean Depth	
Illinois.....	940	1884	1,224	51.7	925	426	499	2.80	1,224	25.6	1.077
Indiana.....	720	1887	939	53.5	657	291	366	2.89	939	26.7	1.256
Iowa.....	1,303	1887	1,527	84.4	1,160	632	528	3.61	1,502	46.1	1.570
Kentucky.....	579	1887	805	41.2	595	254	341	1.97	805	29.4	0.856
Michigan (lower)...	843	1890	987	60.7	720	455	265	2.01	966	33.4	1.005
Michigan (upper)...	72	1898	87	42.7	74	26	48	2.29	87	27.2	1.908
Minnesota.....	1,013	1896	1,158	76.5	920	404	516	3.45	1,132	42.8	2.464
Ohio.....	956	1880	1,243	44.9	908	425	483	2.41	1,243	24.8	0.800
Tennessee.....	518	1891	758	54.3	487	235	252	1.94	758	39.0	1.023
Wisconsin.....	672	1891	779	74.5	620	234	386	3.87	777	49.5	2.037
Aggregate.....	7,616		9,507		7,066	3,382	3,684		9,433		
Average.....		1888.3		61.3				2.85		35.1	1.315
Missouri.....	1,147	1888	1,527	58.7	1,048	710	338	0.95	1,520	33.6	0.432
Grand aggregate..	8,763		11,034		8,114	4,092	4,022		10,953		

try available for water supply and navigation no less than power are interrelated through the ground-water reservoir in such wise that the regimen of each is dependent on the integrity of the ground reserve by which it is chiefly maintained. The essence of a stream resides in its continuity of flow; and this continuity of flow is in nature due absolutely and wholly to continuous supply from the store of ground-water.

12. Since the water vapor which bathes the continent and tempers its climate is not all precipitated on the land over which it passes, but in part goes on over adjacent seas; since the part precipitated as rain and snow and distilled as dew is largely re-evaporated from soil and open water, especially from growing plants whose vitality it sustains; since the residuum mainly soaks into the earth (and should do so wholly, in order to retain the best natural and artificial balance) where it forms a reserve store of ground water for a period averaging perhaps ten years; and since streams are fed chiefly—under the best conditions wholly—from this ground-water reserve, it follows that the fresh water of the country, as a whole, in its forms of vapor, rain, snow, dew, ground-water, lake and stream, is essentially a grand physical unit made up of interdependent parts, and that each stream, despite its essential unity and the interrelation of all its parts, is but an integer within the larger unit.

RELATIONS IN EQUITY

13. Water is the prime necessary of life. Fully five sixths of human food, and indeed a like proportion of the human body, consists of H_2O or water, chiefly in its simple form, partly in chemical combinations. In the human organism water is essential to assimilation, to metabolism or

structural growth, to reproduction—indeed it would appear that no vital process occurs in the absence of water or otherwise than as a manifestation of its inherent properties. In the plants and lower animals yielding human food and clothing, water plays an equally essential rôle—indeed without water the continent would be unproductive and uninhabitable, and the lands of the planet but a dead world.

14. In this as in other countries, water is the primary natural resource. Industrial and other forms of activity on which rest the power and growth of peoples and states depend absolutely on the maintenance of human life and population, which in turn depend on food and measurably on apparel; and whatever its breadth in land and wealth in minerals, no continent can sustain human life and population without sufficient water for drink and for producing from the soil the materials for solid food and clothing. The average crop plant transpires 450 times the weight of its own (dry) substance in water during its growth; and reckoning evaporation from the soil of the moisture required to maintain proper texture, the agricultural duty of water is to produce one thousandth of its weight in average plant crop, or one four-thousandth in grain, or perhaps one forty-thousandth in meat.⁵ Under rigid economy an adult human worker may be sustained for a year by 200 pounds each of bread and meat, with 2,000 pounds of water for drink; or, since the bread and meat require for their production respectively 400 tons and 4,000 tons of water, something over 4,400 tons of water in direct sustentation, apart from that required for ablution and for melioration of climate through aqueous vapor in the air.

⁵ "The Agricultural Duty of Water," U. S. Department of Agriculture Yearbook for 1910, pp. 169-176.

Under irrigation, where alone agricultural water is measured, a five-acre farm supplied with 60 inches of water per year will sustain a family of five, including surplus produce for exchange; this is at the rate of five acre-feet (about 6,800 tons) per inhabitant—at which rate mainland United States might sustain permanently, with its 5,000,000,000 acre-feet of rainfall, a population of 1,000,000,000; the 2,000,000,000 acres of land would indeed support over 2,000,000,000 people if occupied to the density of Belgium (649 per square mile)—but neither land nor any other resource except water affords any measure whatever of the capacity of the country for production, population, power, or perpetuity.⁶

15. As the primary resource, water alone gives value not only to land (as is clearly realized in arid regions) but to all other resources. It is the ultimate basis of values, and can not equitably be regarded as an appurtenance to land or to any other subordinate resource, though in equity land and other resources may be—and in arid countries are commonly—considered practically appurtenant to the natural water.

16. As the prime necessary of life—the ultimate basis of existence for each of the individuals united in the nation—the water of the country is, under that leading principle of our national existence that all men are equally entitled to life, liberty and the pursuit of happiness, the common and indivisible possession of all—a possession in equity inalienable and indefeasible, since no constituent of the nation could alienate or divest himself of his share without surrendering his right to life and so weakening the nation.

17. As the common property and equitable possession of all, water in any form,

⁶“Prospective Population of the United States,” *SCIENCE*, Vol. 34, 1911, pp. 428-435.

together with the appurtenant lands or other resources, may be administered in the public interest by municipalities, states and the national government; but no public agency may in equity alienate, or divest the people of any part of the common interest in the water, nor may it equitably transfer any right to use of the water without just consideration in the public behalf. As the prime necessary of life and the primary resource, and as the common possession of all, water is in itself a special property, and its equitable administration is rightly the most sacred trust confided by the people in their chosen representatives and officers.

18. While the uses of water are diverse, they are not equally essential to life and to that general development of the country on which its power and perpetuity must rest. Since life can exist without it for but a few days, the primary use of water is for drink and other domestic supply, in which it is consumed; since continuous life can be sustained and the generations maintained only through food and clothing produced by its consumption, the secondary use is for agriculture, including irrigation; since the measure of industrial proficiency is the conquest and use of power, the next use of water in order of importance is for mechanical power, in which its substance (or corpus) is not consumed though its movement is utilized; and since the activities of commerce are necessarily subordinate to the primary industries, the least essential use of water is for navigation, in which it is not consumed and only its inert corpus is utilized. Yet the several uses may and should be combined, as when water for domestic supply or irrigation is used for power—and the development of power generally promotes navigation.

19. Since individuals are merged in various business and civic organizations

without loss or impairment of their individuality or their rights and duties as constituents of the nation; since the circulation of rain-yielding vapor is wholly independent of civil boundaries, while the movement of ground-water generally, and the courses of streams largely, are independent of such bounds; since water in artificial conduits and hydro-electric power are essentially commodities and the physical means of carrying them are frequently interstate; and since the chief uses of streams commonly vary in different parts of their courses and often in civil divisions, while the federal government alone can deal with interstate navigation and international waters, no municipality or state or federal agency can claim exclusive jurisdiction over water, or the exclusive right to administer it.

20. Since the chief purpose of statutes and common-law and courts is to prevent inequity, so that their nature is static and their effect generally prohibitive or restrictive or at most permissive, while the activity on which development depends is dynamic and constructive and in its essence progressive (wherefore it is not initiated but merely guided in direction by the static qualities of law and court), it follows that the inherently progressive development in the use of water attending the natural growth and orderly development of the people can best be fostered by combining individual and institutional agency in the highest practicable degree—*i. e.*, by effective cooperation among individuals and both business and civic organizations, including corporations, communities, municipalities, states and federal agencies.

LEGAL RELATIONS

21. Most legal relations affecting the uses of the water of the country are pro-

hibitive or restrictive, or otherwise negative in character; comparatively few thus far developed are positive and constructive.⁷

22. Constructive development of the legal relations of water in eastern United States began with Chief Justice Marshall's interpretations of the commerce clause of the Constitution, largely in *McCullough v. Maryland* (4 Wheaton, 316–437) and more specifically in *Gibbons v. Ogden* (9 Wheaton, 1–240), which established federal authority over navigable streams and navigation; and the next noteworthy constructive step was taken by Chief Justice Taney when he cut loose from the English definition of navigability, showed that English standards are wholly inapplicable to this country, and established the principle that the question of navigability is

⁷Normal development of appreciation and equitable use of water in this country was unfortunately retarded through decisions and sometimes through statutes and state constitutions applying (without shadow of constitutional warrant) principles arising in the English common law, under which water is virtually held a mere appurtenance to land—a usage arising in a small and well-watered but nearly riverless island, and not only illogical in itself (in the impossible condition that a user may remove water from a stream provided he does not impair the flow), but wholly inapplicable to a great continent containing large rivers, though insufficiently watered as a whole. Better standards would doubtless have arisen through importation of the French-Roman law (through the Code Napoleon), under which the water may be said to pertain to the community, save that it was practically limited to the over-watered state of Louisiana; and still better standards were actually introduced into the arid region in the Spanish-Roman law, under which water is allotted by prior claim and continued beneficial use and the land is virtually appurtenant thereto, though this equitable principle has been gradually outweighed by the force of the non-equitable English common law brought in from more populous sections.

one of fact (the *Genesee Chief v. Fitzhugh*, 12 Howard, 443, *et seq.*, especially 456-7)—a principle ever since recognized in this country, save as laxity in federal administration and zeal in state aggrandization have permitted insidious invasion of navigable and necessary source streams by devices for other uses of the water. The third step in the same line (with which advance practically terminates) was marked by the Supreme Court decision in the *Rio Grande* case establishing the power of the federal government to protect the source streams on which depend the navigability of the lower waters (*United States v. Rio Grande Dam and Irrigation Company*, 174 U. S., 690-710)—the oft-quoted *Kansas-Colorado* case, though conformable, being virtually a nonsuit and of little bearing on principles affecting the general relations of water.

23. The most significant advance in the development of legal relations affecting the primary use of water in this country was made in a decision of the New Jersey Court of Errors and Appeals, subsequently affirmed by the U. S. Supreme Court, that the people of the state collectively have a residuary right in the intrastate waters (*Hudson Water Company v. McCarter*, 209 U. S., 349-358), a manifestly valid doctrine which requires nothing but application in other states with respect to their intrastate waters, and extension to the concomitant federal authority over interstate waters in their nature as navigable streams or as sources of such streams, to work a great public benefit. A development of the same equitable principle appears in an opinion of the Supreme Court of Maine that the legislature may prescribe such control of private property in woodlands as may be required to protect public interests in the permanent

water supply conserved by the forests; while the Oregon water law of 1909 by clear implication and the California water law of 1911 in specific terms declare that the waters of the state belong to the people of the state.⁸

24. During recent years the Congress has enacted various constructive laws conformable with and even extending the principles so established by the United States and state courts. The most conspicuous of these is that providing for the reclamation of arid districts by expending certain proceeds of public land sales in diverting water from its natural channels to irrigate dry tracts, thereby promoting the public welfare (conformably with the "General Welfare" clause of the Constitution) through a virtual extension of the public domain in substantial accord with the principle of the Spanish-Roman law under which other resources are essentially appurtenant to water. A related principle was applied in the creation and maintenance, through administrative and legislative action, of national forests designed not only to protect timber but to conserve the water of source streams; and it was definitely established as a national policy within a year by an act providing for the purchase of lands in the Appalachian and White Mountains for the specific purpose of conserving source waters, primarily and ostensibly to protect navigation in the lower rivers—though it was well understood in the deliberations attending the enactment that incidental effects of even greater public benefit would arise

⁸ Some state constitutions, as in Colorado, provide that waters within the state belong to the state, thereby setting up a claim to interstate waters bound to eventuate in expensive and fruitless litigation unless the claims are composed by equitable cooperation and sharing of natural and legal rights and duties between the states and the federal government.

from protection of the streams in their middle courses where they may be used for power development without impairment—indeed with promotion⁹—of navigability below, and from the general conservation of the natural water for all other uses (in fact it would appear that this act was passed in direct response to a popular demand based on manifest equities and recognition of the public good rather than on any narrow construction of common-law or statutes or decisions).

25. Sundry enactments by the congress during recent decades serve to establish what may be considered an inchoate national policy touching the development of water-power on navigable streams whereby, (1) when a franchise is given a private corporation to erect dams the federal government reserves the right to use without charge so much of the power developed as may be required for specific purposes, a reservation which may be deemed in the nature of consideration (and recently this was extended by making the consideration specific and limiting the term of the franchise); (2) when works are constructed co-operatively between the federal government and prospective power users the government reserves rights of administration and for specific uses, and also limits the tenure of the lease or franchise to a specified period; and (3) when the dam is constructed at federal cost the leasing of power developed thereby is authorized under conventional restrictions as to advertising, etc.¹⁰ The policy so initiated is

⁹Not only does each open reservoir for power development hold back the flow of the stream and so shorten the low-water season, but each serves to saturate the adjacent soil and subsoil and rock with an additional volume of water subserving the same end—a volume often comparable with that of the pond itself.

¹⁰The first case is covered by the provision of the general "Act to regulate the construction of

not only naturally susceptible of extension with growing knowledge concerning

dams across navigable waters" (1906) to the effect that "The person owning such dam . . . shall grant to the United States a free use of water-power for building and operating" any constructions which may at any time be required "in the interest of navigation" (U. S. Stat. at L., Vol. 34, p. 386); and this provision is reaffirmed in special laws of various dates. The second case is exemplified by "An Act to enable the Secretary of War to permit the erection of a lock and dam in aid of navigation in the Tennessee River near Chattanooga, Tennessee, and for other purposes" (U. S. Stat. at L., Vol. 33, p. 309), in which it is provided in Section 4 "That in consideration of the construction of said lock and dam, free of cost to the United States . . . the United States hereby grants . . . such rights as it possesses to use the water-power produced by said dam, and to convert the same into electric power or otherwise utilize it for a period of ninety-nine years: *Provided*, that it or they [the grantees] shall furnish the necessary electric current while its or their power plant is in operation to move the gates and operate the locks and to light the United States buildings and grounds, free of cost to the United States: *And provided further*, . . . That the Secretary of War is hereby authorized to prescribe regulations to govern the use of the said water-power and the operations of the plant and force employed in connection therewith." The third case is covered in the provision of the River and Harbor Act approved June 13, 1902 (U. S. Stat. at L., Vol. 32, p. 358), under the item for "Improving Cumberland River, Tennessee, above Nashville," as follows: "And the Secretary of War is hereby authorized, in his discretion, to grant leases or licenses to the highest responsible bidder for the use of the water-power created by said dam, at such rate and on such conditions and for such periods of time as may seem to him expedient . . . : *Provided*, that any lease or license so granted shall be limited to the use of the surplus water not required for navigation . . . : *Provided further*, that before leasing or licensing such water privileges, or issuing permits for the construction and operation of such canals, or otherwise disposing of any water-power or privilege, the Secretary of War shall first advertise the same in one or more daily papers at Nashville, for sixty days immediately preceding, stating specifically the right or

physical relations and the increasing value of power attending the natural growth and orderly development of population and industries, but clearly requires such extension in the interest of general welfare.

26. Federal legislation touching river and harbor improvements has commonly been kept well within the principles laid down by Marshall and Taney, has apparently disregarded the vital principle established in the Rio Grande case, and has shown little progress in the development of standards and ideals conformably to the needs of a great and growing country either for improved transportation or for better use of streams; yet a notable advance has arisen in connection with the work of the Mississippi River Commission which, in cooperation with state officials in Mississippi, Louisiana, and perhaps other states, has extended its work from merely perfunctory revetment of banks for improving navigability in the lower Miss-

privileges proposed to be leased or conveyed, with its exact limitations, inviting bids for the same, and he may, in his discretion, then lease the same for a specific term of years at so much per year, to be paid semi-annually in cash into the Treasury, and the Secretary of War shall reserve the right to reject any or all bids." The extension in the first case is covered in the amended general dam act approved June 23, 1910, by the provisos "That . . . the Chief of Engineers and the Secretary of War shall consider the bearing of said structure upon a comprehensive plan for the improvement of the waterway over which it is to be constructed with a view to the promotion of its navigable quality and for the full development of water-power; and . . . shall provide for improving and developing navigation, and fix such charge or charges for the privilege granted as may be sufficient to restore conditions with respect to navigability as existing at the time such privilege be granted"; and "That the authority granted under or in pursuance of the provisions of this Act shall terminate at the end of a period not to exceed fifty years from the date of the original approval of the project."

issippi to design and location of revetments in coordination with the state work for protecting adjacent lowlands, and has even aided in levee construction—thereby establishing (1) the principle of cooperation between state and federal agencies, and (2) a recognized duty on the part of the federal government so to control regimen in navigable streams as to protect adjacent lands.

27. Repeated enactments by the federal congress in conformity with the work and reports of the administrative departments seem to have established at least in inchoate form a duty of the federal government to take measures looking to the control of all the waters of the country in the public interest: In the War Department the physics and hydraulics of the Mississippi were investigated with a view to control of the river; in the War Department and later in the Department of Agriculture rainfall was measured with reference to drainage basins and stream floods, while of late floods are gaged and flood warnings are issued for the public benefit; in the Interior Department the hydrographic branch of the Geological Survey is gaging all the streams of the country and determining their regimen (including the amount of sediment in the water) with a view to more complete control, the work being sometimes done in cooperation with states; in the same department the operations of the Reclamation Service in diverting streams for irrigation, generally in cooperation with individuals and states, are carried forward vigorously; in several bureaus of the Department of Agriculture investigations and measurements of water are conducted with respect to irrigation, drainage, soil-plant circulation, destructive erosion, etc.—indeed it may be said that the function of the department in dealing

with water and its derivatives—all looking toward increasingly complete control and utilization for the public benefit, while largely in cooperation with individuals and state institutions, the growing knowledge is applied and the control extended from year to year in increasing degree; in the Department of Commerce and Labor the bureau of corporations has made a systematic investigation of navigation with a view to better regulation of both natural and artificial facilities; and in the same department the census bureau has reckoned the actual control of water for irrigation. Under the federal legislation and administrative operations, water is not only measured more accurately than in any other country but is steadily passing under control in the public interest, largely through cooperation with individuals and states, yet always in such wise as to exemplify and establish the common interest of all the people in the water of the country. The advance in this direction during the last decade has been especially rapid; and though apparently little noted, it is among the most significant in our entire history with respect to knowledge, use and administration of the natural waters.

28. Especially in connection with municipalities, a usage has arisen with growing necessities which is congruous with current legal practise in detail, although incongruous with the foreign legal notion that water is a mere appurtenance to land: in all leading cities adequate water supply is provided substantially at public cost, and such lands as may be required to accommodate mains and reservoirs or other works are acquired for the purpose by condemnation or otherwise, while in many cities the lands required for catchment areas are either condemned or purchased, or else arbitrarily protected from contami-

nation—all in accord with the principle of the greatest good to the greatest number; in some cities (notably Los Angeles) the income from power developed by the head of the water is, or is to be, applied in liquidating the cost of both waterworks and land; some municipalities (again notably Los Angeles) allot the surplus water to irrigation for the common benefit, while in many towns and cities the surplus is used in sewerage systems sometimes designed to repay costs through useful disposition of the sewage. The several cases mark growing recognition of the fundamental fact that water is the prime necessary of life and the primary resource, and serve to establish, at least in inchoate form, the doctrine that as population grows dense in relation to the quantity of water, land necessarily becomes a mere appurtenance to that resource on which the lives of the people depend.

29. Under the generally progressive development of legal relations throughout our history, a foundation has been established not only in equity but in law for constructive action by state and federal legislatures, and for judicial decisions more in accord with current knowledge and existing conditions than with archaic standards developed in other countries of different conditions.

30. The essential principle of natural equity on which specific legislation may rest has already found expression, both by statesmen and by powerful associations of citizens including both jurists and publicists, in the incontrovertible proposition—now become axiomatic—that *all the water belongs to all the people*.

PROPOSED APPLICATION OF PRINCIPLES

31. Any action looking toward better utilization and development of the water of the country must be influenced by the

magnitude of the values involved. Since water is the sole source of productivity and habitability, it is the primary basis of all values; and since the property of the country may be appraised at a figure approaching \$150,000,000,000, while the water reserve (stored chiefly in the ground) may be estimated at ten years' rainfall or 50,000,000,000 acre-feet, the one may be balanced against the other as the gold reserve is balanced against the currency whose circulation maintains property values. Reckoned in this way the value of the water reserve may be put at \$150,000,000,000 in gross, *i. e.*, \$3 per acre-foot or 2.2 mills per ton—a reasonable figure, corresponding fairly with the current cost of irrigation water, and far less than any current water rates in cities or even the ordinary margin of rates above the cost of waterworks. In connection with the gross valuation, it may be noted (chiefly on the basis of estimates by the National Conservation Commission toward the end of 1908) that more than 10,000,000 of our people are supplied—largely from protected catchment areas of over 1,000,000 acres—by waterworks, which for 42 cities (not including Chicago, Philadelphia, Cleveland, Cincinnati, *et al.*) cost no less than \$271,159,483 and perhaps as much more for catchment basins, and supply 1,324,300 acre-feet of domestic water,¹¹ worth in round figures computed at \$3 per acre-foot \$4,000,000 annually; that some \$200,000,000 are invested in irrigation works, using 34,000,000 acre-feet of water annually to render productive 13,000,000 acres of arid lands; that the water-power available at a cost comparable with that of steam installation is 37,500,000 horsepower (enough to “operate every mill, drive every spindle, propel every

train and boat, and light every city, town and village in the country”¹²), worth in gross earning power \$20 per horsepower-year or \$750,000,000 annually; that the annual loss through draining away of the ground water in only nine interior states, reckoned at \$3 per acre-foot, is \$442,000,000; that the estimated yearly loss through soil erosion is \$500,000,000; that if navigation were so developed that one fifth of our freight moved by water the annual saving to producers and consumers would be \$250,000,000; and that needed drainage of our 75,000,000 acres of swamp and overflow land would add over \$20 per acre above the cost of draining (or \$1,500,000,000), to our national wealth and provide home-sites for 5,000,000 to 7,500,000 families. Even the most conservative figures indicate that the development, control and utilization of water raises the largest and one of the most pressing economic issues now before the American people.

32. Since the uses of water are interdependent and most of the physical relations interstate, complete control may not be exercised justly either by any single state sovereignty or by exclusive federal sovereignty; so that concurrent legislative and administrative action is required by states and the municipalities within them and by the federal government.

33. Since under the Constitution the federal government is primarily responsible for the general welfare, requisite action may properly, and in view of the urgent demand should without needless delay, be initiated by the congress.

34. The magnitude and complexity of the interests affected, the delicacy of the legal relations involved, and the dearth of both exact knowledge and practical experience concerning the several uses of

¹¹ Report of the National Conservation Commission (60th Congress, 2d Session, Senate Document 676), 1909, Vol. II., p. 178.

¹² *Ibid.*, Vol. I., p. 41.

water, all indicate that action taken at this juncture should be constructive and developmental rather than definitive. While the relations in equity seem clear, and while the legal relations appear to form a firm foundation for a broader legal structure than has hitherto been attempted, the technical experience needed to guide definitive legislation remains inadequate: it is barely over a decade since electric power transmission began reconstructing industries, since the internal-combustion engine began closing the age of steam (which may reopen under the steam-turbine), since steel-concrete construction began revolutionizing the use of resources, since irrigation began opening a new era in standards of production; and the concepts of even the most advanced jurists and law-makers can hardly be quite abreast with, much less far in advance of, the technical experience attending these industrial developments. Moreover, the concept of water as a common possession in equity of all the people remains novel in many minds, and is bound to result in new and unforeseeable interrelations among individuals and civic organizations, and especially between states and the federal government—interrelations that can be adjusted and regulated in the common welfare only as common experience grows with advancing applications of increasing knowledge. It would no more be practicable to establish definitive regulations for the use of the natural waters to-day than it would have been to create our magnificent railway system by fiat 80 years ago, to establish our intricate banking system when the Constitution was framed, or to found by a stroke of the pen 20 years ago the Department of Agriculture with its hundreds of scientific experts, made such by long-continued training. The need for

action presses; but wise action to-day can be no more than preparatory for, and directive of, prospective and inevitable development.

35. In view of the interstate relations of our natural waters, action by the congress should be framed with special reference to that comity with and among the states best maintained by sharing, rather than by disputing as of old, common interests—a course in which useful experience has been gained in the Mississippi River Commission and Reclamation Service, as also in the Forest Service and other leading bureaus of the Department of Agriculture; and the federal legislation should not merely form a model for states, but should authorize necessary administrative action directly and in conjunction with states.

36. Since practical experience is a *sine qua non* for wise legislation, early state and federal enactments should be framed in general terms, entrusting the actual work to administrative agencies under proper restrictions and provisions for reporting progress to the legislative authority, much as in the statutory authority for state and federal departments.

37. While the magnitude and importance of the issue involved in control and utilization of water would warrant the creation of a federal department to meet it, such action at this juncture might be premature—especially since the more pressing requirements may be met through existing departmental facilities. The several considerations point toward a presumptively temporary federal administrative agency, created or empowered to make investigations and take action looking toward the progressive control and regulation of the water of the country with respect to all uses, both directly and in cooperation with states and when needful with individuals,

corporations, communities and municipalities—such agency to report through the executive annually and at such other times and in such modes as the congress may require. It should be among the first duties of the federal agency to confer with officers or other competent representatives of states concerning water-power and other uses of water with a view to determining means of effective cooperation, equitable sharing of rights and responsibilities, estimates of cost of works required for state and federal use, reasonable rates for domestic and irrigation water supply and for power, and all other matters of common concern to the state and federal governments—the determinations to be reported to the state legislatures and to the congress as a basis for further action in the public interest in accordance with the righteous principles of the greatest good to the greatest number for the longest time.

38. While it is not necessary and might be inexpedient for current federal legislation to specifically declare the principle that all the water of the country belongs to all the people of the country, the enactments may not equitably, nor judiciously in view of the trend of that public sentiment in which lies the power of the nation, be open to construction as dissenting from or denying that principle; for already this has become part of the body of ethical conviction underlying American character and constituting its strength.

W J MCGEE

UNIVERSITY EXTENSION AND THE STATE UNIVERSITY¹

THE state university is a public service corporation. It is supported by the public presumably *for* the public. Until within

¹Presented before Section L, American Association for the Advancement of Science, at the Minneapolis meeting.

comparatively recent years, few questions have been asked as to the quality and comprehensiveness of the service offered by the university to this constituency, but the time has arrived when not only educators, but intelligent laymen, including both employer and employed, are asking to what degree the relation of the people as a whole to the educational system has been recognized.

What proportion of the young folk who become high school students are served in future years by the university? What proportion of those who remain in school for elementary training only, reap more than the most meager benefits from our so-called popular education?

The high average percentage of illiteracy in the United States, the low comparative degree of efficiency in the industries and the avidity with which opportunities for further training are embraced by persons who have completed their formal education, all point to a fault in the existing system, for which there is at present no generally adopted remedy.

It is not my purpose to dwell upon the shortcomings of our public education, nor to enlarge upon the fact that statistics relating to school attendance would give less cause for discouragement if we recognized in our public schools the value of training for efficiency. A radical change in the curriculum, aimed at retaining the interest of the pupil by showing him the value of his education as a usable asset, would tend to lengthen the term of school life for both boys and girls and, in many cases, would prolong it into and through the university.

In view of this lack of what may be called vocational applications in school training, it is not difficult to understand the reason for the almost overwhelming demand from persons engaged in business pursuits for an opportunity to enter, how-